Indian J. Phys. **49**, 350-354 (1975)

Gamma-gamma-gamma angular correlation method for the study of the cascade 589-296-316 kev in Pt^{192}

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(*Received* 2 *January* 1975)

Three NaI(Tl) detectors (Spectrometers) mounted in the plane of the table (two detectors are fixed perpendicular to each other and third detector is movable in the opposite quadrant of the two fixed detectors) are used for the coincidence and angular correlation studies for the triple gamma cascade 589 keV→296 keV→ 316 keV in Pt^{192} from the decay of Ir^{192}. The method of tirple angular correlation is described and multipolarity of the 296 keV transition is determined.

1. INTRODUCTION

The gamma-gamma directional correlation in the decay of Ir^{192} has been studied by many workers. Khan *et al* (1969) and Hirshfeld & Hoppes (1970) studied it with the aim of the determination of transition mixing ratios for various gamma transitions. Energies of the gamma-rays of 296 keV, 308 keV and 316 keV are very close and also energies of gamma-rays of 589 keV, 604 keV and 612 keV are close. Therefore, large correction or extrapolation is needed for the interpretation of the results in angular correlation studies even using Ge(Li) detectors. In order to overcome these difficulties an attempt has been made to study the angular correlation of the cascade of three gamma-rays i.e., 589 keV-296 ke4V-316 keV in Pt^{192}.

2. EXPERIMENTAL

There are two simple geometrical considerations for the mounting of the three detectors for triple angular correlation studies.

(1) When all the three detectors are in one plane (i.e., in the plane of the table) two of the detectors are fixed perpendicular to each other and the third detector is movable and can be kept at various angles. Let us call it *P* geometry.

(2) When two of the detectors are in the plane of table (one of them is movable) and the third detector is perpendicular to the plane of the table. Let us call it *C* geometry.

If the three gamma-rays are of different energies then, it is simple to choose them in photopeaks in three different detectors but if the three gamma rays are of the same energies, then we can look for a proper geometry of the mounting of the detectors.

When all the three gamma rays are of same energies then angular correlation is isotropic in the geometrical mounting P but is not so in the geometrical mounting C, (the details are given by Singh *et al* (1971)). Therefore, the geometrical mounting C was taken for the angular correlation studies in this case.

Now two gamma-rays are of almost the same energies and the third one of different energy as it is taken for this study, of the cascade of 589 keV-296 keV-316 keV in Pt^{192}. The triplet gamma angular correlation coefficients were calculated for the P and C geometry by method given earlier (Singh *et al* 1971, 1972). If we take all the three gamma rays to be pure E_2 with spin sequence $4 \to 2 \to 2 \to 0$, the angular correlation coefficients are as follows :

(i) P geometry of the mounting of detectos mentioned above

$$A_2 = -0.182, \qquad A_4 = 0.2471,$$

(ii) C geometry of the mounting of detectors as mentioned above

$$A_2 = -0.0493, \qquad A_4 = 0.0005.$$

The anisotropy is much large in geometrical mounting P compared to geometrical mounting C. Therefore, in this case geometrical mounting P is preferred. In this geometry of the mounting the 589 keV gamma rays is detected by the detector marked I as given in figure 1 and other two detectors marked II and III are assigned to detect both 296 and 316 keV gamma rays. Therefore two considerations are possible.

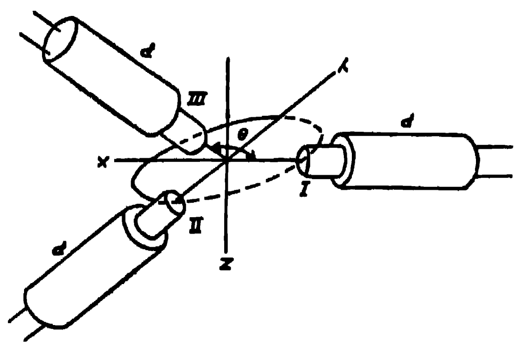

Fig. 1. The arrangement of detectors. Detector marked I and II are fixed and detector maked III is movable for the angular correlation studies. Detector marked I detects the 589 keV gamma ray and other two detectors (II and III) detect the gamma rays at 300 keV in 4 volts channel width.

(a) When 296 keV is detected by detector marked II and 316 keV is detected by the detector marked III which is movable making an angle θ with the detector marked I shown in figure 1.

(b) When 316 keV is detected by detector marked II and 296 keV is detected by the detector marked III the movable detector, Both the situations are equally probable therefore the average of the two is to be taken.

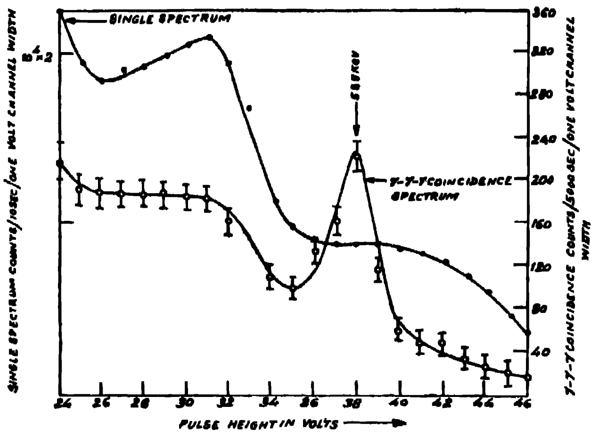

Fig. 2. Triple gamma coincidence spectrum along with a single spectrum after subtracting the chance counting rate.

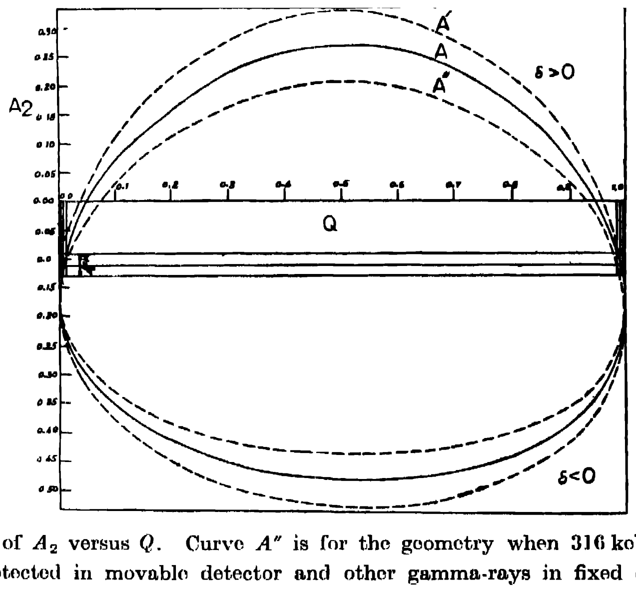

Fig. 3. Plot of A_2 versus Q. Curve A'' is for the geometry when 316 keV gamma-ray is detected in movable detector and other gamma-rays in fixed detectors and curve A' is for the geometry when 296 keV gamma-ray is detected in movable detector and other gamma-rays in fixed detectors. Curve A is for mean of the two geometries.

The details of the experimental setup is described earlier (Singh *et al* 1971, 1972). Triple coincidence spectrum is given in figure 2 which is taken selecting gamma-rays at the photopeak in two detector (spectrometers) at 300 keV in 4 volts (1 volt = 15 keV) channel width for gamma-gamma coincidence gate and scanning the spectrum in other detector (spectrometer) for triple gamma-ray coincidence spectrum. The detector detecting 589 keV at the photopeak in 4 volts channel width and one of the detector detecting gamma-rays at the photopeak of 300 keV in 4 volts channel width are fixed perpendicular to each other and other detector detecting gamma ray in 4 volts channel width is movable in opposite quadrant in the interval of 22.5° for angular correlation studies. The $W(\theta)$ is obtained by the method of least square fit. The solid angle correction is not applied. This correction is included in the theoretical calculation. The $W(\theta)$ is as follows :

$$W(\theta) = 1-(0.11\pm0.021)P_2(\cos\theta)+(0.062\pm0.03)P_4(\cos\theta)$$

Considering the spin for the cascade

$$4+\xrightarrow[E_2]{589\text{ keV}} 2+\xrightarrow[(M_1+E_2)]{296\text{ keV}} 2+\xrightarrow[E_2]{316\text{ keV}} 0,$$

and considering both 589 and 316 keV transition to be pure E_2, the mixture of dipole and quadruple in 296 keV is determined. This is done by plotting (which is given in figure 3) the angular correlation coefficient A_2 versus $Q(Q = (\delta^2/(1+\delta^2))$ where δ is amplitude mixing ratio.

The experimental value of A_2 cuts the mean curve giving $Q_1 = 0.005^{+0.005}_{-0.003}$, $Q = 0.990^{+0.006}_{-0.004}$, $\delta > 0$. Q_1 is rejected as 296 keV is predominantly E_2 transition. Q_2 is accepted which gives $\delta = +10^{+3}_{-2}$ (Biedenharn & Rose 1953)convention has been followed. Results of δ by different workers are displayed by Hirshfeld & Hoppes (1970). Our value lies in the same range but with opposite sign. The opposite sign of δ has been obtained by (Ofer 1959) for the middle gamma-ray of the cascade of three gamma-rays when angular corelation of the first and second gamma-rays and angular correlation of the second and third gamma-rays are done. Therefore we should get (—) sign (or phase) in triple gamma-rays angular correlation due to phase convention of Biedenharn & Rose (1953). Therefore the actual sign of δ shall be positive (or negative) if the experimental value is negative (or positive). Therefore, the sign of δ in this study is also (—) and therefore δ 10^{+3}_{-2}.

Acknowledgment

We are thankful to Department of Atomic Energy, Government of India for the financial support for this project,

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